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RELATIVE HEIGHT OF LIGHTNING ORIENTATION

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[A Digest]

In the period 1932 to 1941 considerable research was carried out by scientists of the VEI (All-Union Electrical Engineering Institute) on the subject of selective properties of spark discharge to determine the manner of their formation and the protective capacity of lightning rods in different locations. Among the researchers whose reports appeared in "Elektrichestvo," "Report of VEI," and "Byulleten' of VEI" were A. A. Akopyan, I. S. Stokol'nikov, L. I. Ivanov, K. Shaposhnikov, and the author of the present report.

Stokol'nikov's method of inhibiting the development of a leader by resistance (1937) made it possible to obtain time photographs of high-voltage spark-discharge formation. Further research established the dependence of the protective action of lightning rods on the absolute humidity of air, and in 1939 the author was able to evaluate the dependence of the selective discharge paths on the rate of formation of discharge leaders. In this connection, research on working models brought out the fact that protective zones for different size models, but with the same relative dimensions, varied from anticipated values because the sectional and average velocities of the discharge leaders changed as the dimensions of the model were changed. By controlling the rate of formation of the discharge leaders it was possible to obtain equivalent protective zones in both cases.

An experimental method was developed by the author for determining the influence of relative height H/h (where H equals height of discharge or "storm" center, and h equals height of grounded rod) on the discharge pattern.

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A graph of eight curves was plotted for H/h ratios of 2, 5, 10, 20, 40, 80, 120, and 240 with r/h (r equals horizontal distance of "storm" center from rod) plotted on x-axis (0 - 20) and hit ratio (hits divided by total discharges) on y-axis. Analysis of these curves reveals the following facts: (1) for small values of H/h the rod was struck by every discharge when the storm center was overhead or within close range; (2) the percentage of hits for various positions of the storm center with respect to the rod was less influenced by this position as the relative height (H/h) increased -- e.g., for H/h equals 2, all the discharges hit the rod from r/h equals 0-1.0, while none hit the target after the storm center moved beyond r/h equals 2.2; on the other hand, for H/h equals 120 the overhead hits were less than 40 percent, but hits continued to take place up to r/h equals 20. In other words, as the height of storm center relative to rod height increases, the rod loses its ability to direct the discharges at itself. It should also be noted that for curve 4 (H/h equals 20) the data were compiled for different readings of the mercury column (2.9, 4.4 and 10.5 millimeter) without any appreciable deviations noted.

The second graph was composed of four curves showing the number of overhead hits as a function of relative height H/h for different average velocities V_a of the leaders (V_a equals $5 \cdot 10^7$, $2.4 \cdot 10^8$ cm/sec both for a rod and a cable). These curves show that: (1) the ratio of hits is greater at the higher leader velocity, except for small H/h ratios when the discharges hit the target in all cases; (2) for H/h equals 0 to 50 all the discharges hit the target (both rod and cable) at the higher leader velocity; (3) the curves of hits slope downward continuously (concave upwardly) -- at H/h equals 200 the number of hits varies from 12 to 48 percent (the rod curve for $2.4 \cdot 10^8$ cm/sec is the lowest -- i.e., least hits).

It may be concluded from this second graph that: (1) the relative height at which leaders will be oriented toward a grounded rod or cable increases as the rate of leader formation (V_a) increases; (2) for the lower rate (V_a) of leader formation, the cable received more hits for all values of relative height H/h , whereas for the higher V_a the rod received slightly more hits until H/h equals 100, after which the cable was increasingly a better target than the rod.

Under actual conditions, the average velocity of the first lightning leaders can be differentiated in their order of magnitude, although their values are usually considerably greater than the leaders in laboratory uninhibited high-voltage discharges. It may be assumed that the average rate of formation of most lightning leaders is of the order of 10^8 centimeters per second and over.

The table below gives the protection angles for a single grounded cable for calculated heights of leader orientation of $H/h = 10$ and 40.

H/h	h_0/h	Angle of Protection	Probability of Being Struck	Remarks
10	0.75	35°	--	Data of A. A. Akopyan
40	0.75	48°	--	Extrapolated data of A. A. Akopyan
40	0.75	45°	10^{-6}	A. P. Belyakov's formula (1939)
40	0.9	44°	10^{-6}	A. P. Belyakov's formula

As may be seen from the table, increasing the value of H/h from 10 to 40 results in a larger protective angle. This was also found to be the case for single lightning rods.

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